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Integrated infrastructure for CO₂ transport and storage in the west Mediterranean

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Abstract

COMET - Integrated infrastructure for CO₂ transport and storage in the west Mediterranean- is a joint research Project co-financed by the European Seventh Framework Programme (FP7), which started on January 2010. Carbon dioxide Capture and Storage (CCS) is a CO₂ abatement option that can contribute substantially to the ambitious targets needed for climate stabilization. The significant role foreseen for CCS is based on several conditions, like the availability of a CO₂ transport infrastructure or construction of such an infrastructure within the near future. The need to have a suitable transport infrastructure, its implications over time and its related costs have only more recently attracting the attention and getting priority in the R&D agenda of the European Countries. This is partly because research on CO₂ transport and storage needs to be realized at the local-regional level, unlike the technological research on CO₂ capture which is not country dependent. In this context, COMET focuses on assessing CO₂ transport and storage in a geographical area that until now has received little attention: the West Mediterranean area, specifically, the Iberian Peninsula and Morocco.

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1. Introduction

Carbon dioxide Capture and Storage (CCS) may play a significant role as a CO₂ abatement option, contributing substantially to the ambitious targets needed for climate stabilization. The 2010 Energy Technology Perspectives report of the International Energy Agency estimated a capture potential via CCS of about 19% of global CO₂ emissions in 2050 [1], with other studies showing similar ranges [2]. This share is the result of implementing CCS in

the power and industrial sectors [1]. The significant role foreseen for CCS is, however, based on four main conditions:

1. CO₂ capture technology will be available;
2. The option will be competitive;
3. Sufficient and suitable underground storage capacity will be available and,
4. CO₂ transport infrastructure is available or construction of such an infrastructure can be built within the near future.

Most research has focused, so far, on reaching on time the first three conditions. The need to have a suitable transport infrastructure, its implications over time and its related costs are, more recently, attracting attention and getting priority in the R&D agenda [3]. The challenge for the future of transport technology is to develop long-term strategies for CO₂ source clusters and CO₂ pipeline networks that optimize source-to-sink transmission. To address this challenge, governments need to initiate regional planning exercises and develop incentives for the creation of CO₂ transport hubs across all regions [4, 5]. Unlike research on CO₂ capture technologies, which is not country dependent, research on CO₂ transport and storage needs to be developed at the local-regional level.

The need for developing a common strategy for CCS deployment in the West Mediterranean (Portugal, Spain and Morocco; Figure 1) is related not only to the geographical proximity but also to:

- The increasing connections between the energy and industrial sectors in the area;
- The continuity of sedimentary basins that can act as potential storage reservoirs;
- The existing experience in managing a large gas transport infrastructure.



Figure 1: Geographical area of the study - West Mediterranean [6]

Spain and Portugal emitted about 484 Mt CO₂eq in 2008 and, together, they accounted for nearly 10% of the European Union (27) GHG emissions [7]. Drastic reductions are necessary to meet the commitments prepared within the EU and worldwide. Morocco's emissions were about 45 Mt CO₂eq in 2006 [8] and these are expected to grow, in a “business as usual” scenario. The objectives on abating CO₂ emissions can only be achieved by timely decisions on the deployment of mitigation options in the region, including CCS.

There are already strong connections between the energy sectors across this geographic area. On the one hand, Morocco, Portugal and Spain already cooperate in terms of transport of natural gas. The pipeline that supplies the Iberian Peninsula with natural gas from the Algerian fields crosses Morocco for a large extension (Figure 2). Furthermore, Spain and Portugal have signed an agreement to create an Iberian electricity market (MIBEL), with strategic decisions being taken by the energy companies on the basis of the supply/demand of the whole Iberian Peninsula. In the oil refining and supplying sectors, there is also an increasing connection between the major

Spanish and Portuguese companies, which operate freely in both countries and cooperate in the management of pipelines. It is, thus, likely that the European Commission targets for reduction of GHG emissions also need to be addressed in an integrated manner by the two countries.



Figure 2: Existing pipeline network linking Portugal, Spain and Morocco [9]

Morocco, on the other hand, is going through a period of economic growth. A steady increase on energy demand has driven the construction of new fossil based power plants, and the Moroccan Ministry of Energy has developed an energy plan for the coming 6 years that includes additional power generation capacity of 2640 MW coal fired, 2472 MW of Natural Gas Combined Cycle and 700 MW of Gas turbines and diesel plants [9]. Morocco also has extensive reserves of Oil Shale, estimated at around 50 billion barrels, and the Moroccan Ministry of Energy has unveiled plans to develop it both, for direct use in power generation and for petroleum production when technology is available [9]. Morocco is also the third world's largest producer of phosphates and has an important fertilizer industry, a major contributor to CO₂ emissions. Within the framework for economic development, energy demand and development of domestic fossil fuel and mineral resources, CO₂ emissions of Morocco are most likely to increase in the near future, despite the global need for GHG reduction.

As such, a similar challenge is faced by the energy sector in both sides of the West Mediterranean area: the need to reduce CO₂ emissions, without compromising energy supply and economical development. Under such conditions, CCS in geological formations may become a common attractive option to Morocco, Portugal and Spain, also because these countries share some offshore sedimentary basins that are likely to be potential suitable reservoirs for CO₂.

Due to the scale of the challenge and the transboundary nature of potential geological reservoirs, it is quite possible that the implementation of CCS at a commercial scale will involve cooperation between countries. Such cooperation will have to consider the fact that, if the storage capacity is available, it may be more cost efficient to

use common formations for regional storage of CO₂, provided an integrated transport and storage network can be developed, and that this is less expensive over time than isolated infrastructures developed independently in each country.

Optimizing transport costs requires a balanced decision on transport modes and a rigorous matching of CO₂ sources and sinks over time. The three factors named above, i.e., the existence of common transport network (i), the existence of transboundary sedimentary basins (ii) and an energy and industrial sector becoming increasingly interlinked (iii), constitute the rationale for COMET project - Integrated infrastructure for CO₂ transport and storage in the west Mediterranean- a joint research Project co-financed by the European Seventh Framework Programme (FP7), to assess the economic and technical effectiveness of a common infrastructure for CCS development at a Trans-Mediterranean scale.

2. State-of-the-art

Extensive research within the field of CCS has been carried out internationally over the past years. To a large extent, CCS research has focused on three main areas: developing knowledge and technology related to CO₂ capture from power production and to some extent the energy intensive industry; estimating capacities for long-term CO₂ storage and developing frameworks for CO₂ risk assessments. However, when it comes to analysing the whole CCS chain, limited research on transport and storage infrastructures is reported so far [10, 11, 12].

Technically, CO₂ can be transported through pipelines or pressurised vessels in the form of a gas, a dense fluid or in the sub-cooled liquid state. Pipeline transport is expected to be the more promising means of transport where long distances must be covered and for significant quantities of CO₂. Despite the fact that CO₂ transportation has not been extensively applied in Europe to date, it is technically feasible, if related design, contraction, operational guidelines and standards become available in the near future.

The EU research project GESTCO (1999-2003) [13] carried out an extensive inventory of industrial and energy related CO₂ sources (larger than 100kt/yr), potential geological storage sites and transportation data for seven European countries. A Decision Support System (DSS) was developed to determine whether the capacity of the selected sink would be sufficient to store the CO₂ emitted from a certain point source. This tool assessed the most cost-effective route from one source to one sink by taking into account terrain conditions, land use, topography, rivers and the existing pipeline corridors.

The CASTOR - CO₂ from Capture to Storage - was a European research project (2004- 2008) [14] with the objective to develop and validate all innovative technologies needed to capture and store CO₂ in a reliable and safe way. Besides aiming for a major cost reduction of post-combustion capture technologies and the increase of public acceptance in CCS, a key target of this project was to develop an integrated strategy combining capture, transport and storage. It developed a tool to facilitate the economical analysis of a CCS strategy which derived the optimal CO₂ flow through the pipeline network and the associated dimensions and costs of such a pipeline.

GeoCapacity (2006-2008)[15] is the follow up of the GESTCO programme. This EU project covered 22 countries most of which were not included in the GESTCO project. The DSS economic evaluation tool has been further extended within GeoCapacity to facilitate multi-source and multi-sink evaluations instead of one-to-one connections.

There have been also a series of research projects focusing specially in the North Sea area [16]. For instance, a study made by the North Sea taskforce, examined possible pathways for a CCS pipeline infrastructure connecting large UK and Norwegian sources with appropriate sinks in the North Sea and reported on the implications for both countries. It was examined the role that a pipeline infrastructure for CCS could play in reducing CO₂ emissions from both countries. The project team developed a comprehensive database of onshore CO₂ sources and offshore CO₂ sinks. A list of CO₂ tolerant pipelines in the North Sea was also developed and the potential for reuse of existing oil and gas infrastructure for CCS was explored. A CCS network model was developed permitting relatively rapid

assessment of network configurations. It calculated detailed capacity requirements and costs for CO₂ capture and transport to provide estimates of capital and operation expenditure, captured CO₂ and avoided emissions. Another example is the study carried out in the context of the FENCO ERA_NET tender [17]. The research project aimed to analyse the possibilities for building an offshore pipeline infrastructure that transport CO₂ from countries in the North Sea area (Denmark, Germany, the Netherlands, the United Kingdom) to the Utsira formation.

The research projects so far covered specific locations and topics and thus additional research is needed to find a systematic solution to tune the storage requirements, the producer's requirements and the transport system's requirements, with the objective of reducing total cost. The first step will be to establish the first large transport lines in a system and from then on, to establish a large integrated system. However, there are no studies relating to the costs and logistical problems for joining such a large network for countries such as Spain, Portugal and Morocco. For these countries, linking to a North-European CO₂ pipeline network may prove to be economically unfeasible. It is therefore necessary to look for alternatives that rely on the regional storage capacity: this is at the main core of COMET.

3. COMET project

COMET is a three year project (2010-2013) aiming to identify and assess the most cost effective CO₂ transport and storage infrastructure able to serve the West Mediterranean area, namely Portugal, Spain and Morocco. This is achieved considering the time and spatial aspects of the development of the energy sector and other industrial activities in those countries as well as the location, capacity and availability of potential CO₂ storage geological formations. Special attention is given to a balanced decision on transport modes, matching the sources and sinks, addressing safety and lifetime objectives, meeting optimal cost- benefit over time for a CCS network infrastructure as part of international cooperation policy.

The consortium is coordinated by LNEG (Portugal), and comprises 7 research institutions, 4 Universities, 1 SME and 5 energy companies from 6 European countries and Morocco. COMET aims to optimise the connection between sources and sinks by comparing the several possible transport modes (pipelines, trains, ships and trucks) and existing and to be built infrastructures. It aims to find the least-cost transport mode and routes from source clusters to sinks. It is expected that each source cluster will be rigorously matched to the most suitable sink, while minimising the required investment in infrastructures and taking advantage of the effect of scale associated to an integrated infrastructure.

The overall strategy of COMET comprises four fundamental tasks, subdivided in seven work packages (Figure 3):

1. Harmonized inventory of present and future CO₂ sources and storage capacities in the region
2. Least cost modelling of national and regional energy systems
3. In-depth assessment of selected transport networks
4. Dissemination of information

Harmonized inventory of present and future CO₂ sources and storage capacities in the region

This task will include the identification and clustering of point sources, according to their proximity. Historical trends and location of the energy sector and industrial sector, as well as current plans for future development and climate reduction policy targets, will be used via MARKAL/TIMES models [18] to get an estimation of the CO₂ emission volumes up to 2050 (WP2 and WP5). The CO₂ sources will be grouped into clusters according to their proximity by means of Geographical Information Systems (GIS) (WP4).

Potential CO₂ storage sites, already known in Spain [15] and preliminary studied in Portugal [19] and not yet studied for Morocco, will be identified and the available theoretical storage capacities will be estimated using homogeneous methodologies (WP3). The storage sites will be grouped into clusters according to their proximity by means of Geographical Information Systems (GIS) (WP4). Particular focus will be given to the transboundary

sedimentary basins, where storage capacity (as well as responsibility and liability) will be shared amongst the three countries. Clustering of sources and storage sites will be performed on an integrated basis, allowing transboundary clusters of sinks and/or sources, which constitute an innovation compared to the work carried out by Geocapacity [15].

Cost estimates will be made for CO₂ capture and storage considering to the extent possible source specificities as well as characteristics of the storage sites. The energy companies participating in COMET will play an important role in this task, which thus can improve the reliability of technological cost data.

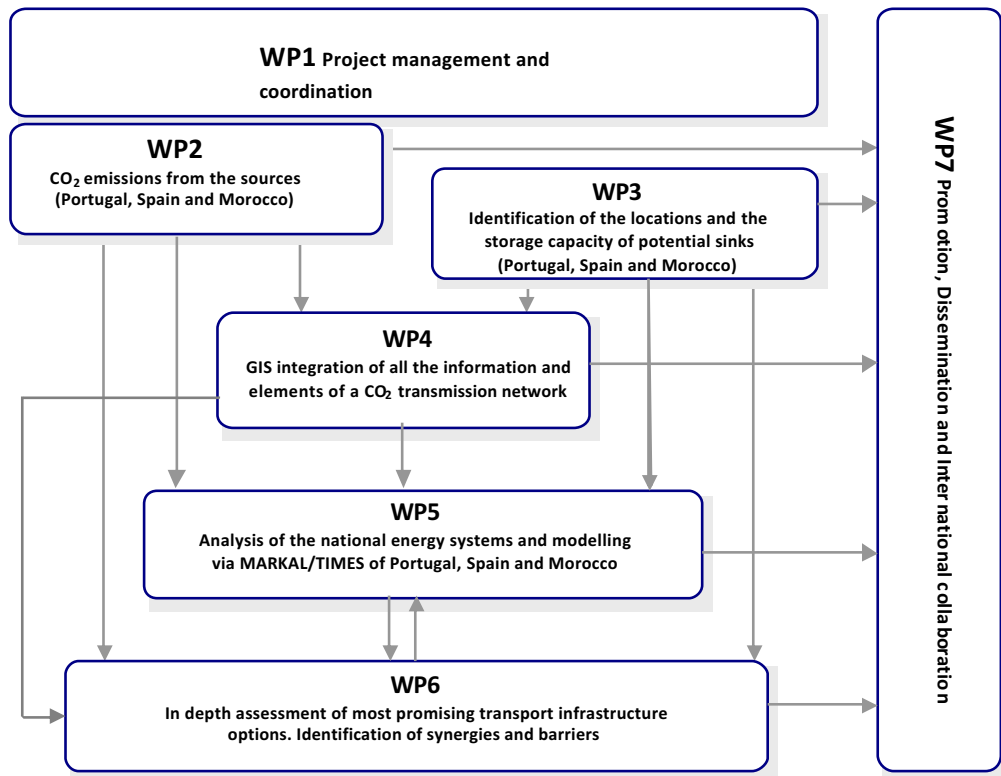


Figure 3: COMET workpackages breakdown structure

Least cost modelling of national and regional energy systems

This task will involve the Geographic Information Systems (GIS) integration of all the information and elements of a CO₂ transmission network. Routing models in GIS will be used to find the best route(s), and associated costs, between source and sink based on the land use maps and on the existing roadways, main ship routes, train lines and pipeline corridors (WP4); MARKAL/TIMES will find the most cost effective source-sink combination between the three countries, taking into account the possible future development of the whole energy sector in Morocco and in the Iberian Peninsula (WP5).

The information on CO₂ sources, storage capacities and CO₂ transportation routes will be implemented into the MARKAL/TIMES models for Spain, Portugal and Morocco. The geographical constraints affecting CCS will be modelled as national cost curves for CO₂ capture, transport and storage in each of these countries. For this, several sub-tasks will be carried out:

- Development for each country of “business as usual” (BAU) scenarios for energy and materials demand projections and policy constraints (namely CO₂ caps and prices);

- Preparation and test of a MARKAL/TIMES model for Morocco, compatible with the existing Portuguese and Spanish models,
- Design of the inter-country trades and interfaces among the three models (regarding electricity and CO₂ trade, among others) with the aim of linking the three national models,
- Improvement of the existing information on CCS in the Portuguese and Spanish TIMES models and its implementation in the Moroccan model, considering the modeling of CO₂ capture in power and industrial sectors, transport pipelines and storage facilities and including possible spatial disaggregation of national CO₂ sources;
- Identification of the cost-effective CCS potential and the most cost effective source-sink combination between the three countries in several scenarios.

In-depth assessment of selected transport networks

Comparative cost estimates between the multiple transport options and combination of those (ships, trains, trucks and pipelines) will result in a selection of the most promising transport infrastructures for each studied scenario. The selection of transport infrastructures will be the result of policy measures, transport costs and technical-economic evaluation of different options (such as baseline without any mitigation policies, scenarios with mitigation policies but with and without CCS, and/or with and without regional integration, etc.) (WP6).

For the in-depth assessment, several scenarios will be built. Among the different drivers to study in each scenario are: CO₂ emission caps, CCS technologies learning curves with emphasis on different transport options, energy demand, CCS public awareness, CO₂ storage potential and primary energy costs. For each of these scenarios an analysis of the most effective CCS technologies and sites combination will be made, followed by policy recommendations on: 1) the role of CCS, 2) the most cost-effective routes of CCS implementation in the Iberian Peninsula and Morocco region, 3) furthermore for the most promising routes. It will be analyzed barriers and synergies for their implementation. This will take into account economic, organizational and financial aspects, and will include active participation of national and regional stakeholders.

Promotion and Dissemination of information

The dissemination strategy of the project's outcomes will also be promoted, including publications, newsletters, workshops proceedings, and Web-based activities (WP7). Particular focus will be given to three dissemination and information strategies:

- Workshops involving stakeholders of the three countries, focusing on the need to clarify whether an increasingly interlinked energy system should include an integrated approach to solving the CO₂ emissions management in the West Mediterranean and the synergies and barriers of such approach;
- Side-events during official meetings of the 'Union for the Mediterranean', an initiative launched in 2008 and aimed at upgrading the EU's relations with its neighbours from North Africa and the Middle East that border the Mediterranean Sea;
- Promotion of the outcomes of project amongst non-technical or non-scientific audiences, since CCS technology is largely unheard of in any of the three target countries. Within that scope a number of training and dialogue events directed to students and other stakeholders willing to learn about CCS and the project will be promoted, and some information material will be produced.

A COMET Web site in English was created (<http://comet.lneg.pt>) and will be continuously updated with reports on the climate change challenge and the potential role of CCS as a GHG mitigation option as well as information on the progress of the different work packages. Parts of this material will be translated to the national languages of the partners: Portuguese, Spanish, French and Arabic.

4. Conclusions

COMET project will generate insights into the potentials and constraints of developing a common regional strategy to design and rationalize a CCS network infrastructure, in order to help a group of countries to reduce their CO₂ emissions without compromising energy supply and economic development. Of particular relevance is the focus on placing together two industrialised countries, Spain and Portugal, and one developing country at fast

economic growth, Morocco, which all ratified the Kyoto Protocol. Gaining insights into this kind of cooperation will be of high interest for stakeholders, not only from these 3 countries, but also from Europe, the Mediterranean region and the rest of the world. Furthermore, it is expected that this project can benefit from the latest developments of other initiatives worldwide and viceversa.

COMET is designed to be the first concerted effort for the deployment of CCS in the West Mediterranean area, with common energy and development interests. The consortium is composed of high-profile researchers in the field of CCS and major industrial partners. The first group will assure the transfer of knowledge gathered in COMET to increase the possibility of making CCS a reality in other regions with similar features to the West Mediterranean.

COMET aims to be an important step towards the safe and commercial deployment of large scale near zero emission power plants in SW Europe and North Africa.

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